

1 INTRODUCTION

The System Engineering Manual (SEM) is a “how to” guidebook. The SEM defines major System Engineering (SE) elements and establishes best practices regarding application of these elements to the National Airspace System (NAS). The SEM is a selected compilation of those proven practices within the SE domain that are deemed most appropriate to analysis, planning, design, acquisition, lifecycle support, and management of Federal Aviation Administration (FAA) programs.

There are many definitions of SE in textbooks, professional journals, and classrooms. The following definition has been selected for the SEM:

A discipline that concentrates on the design and application of the whole (system) as distinct from the parts. It involves looking at a problem in its entirety, taking into account all the facets and all the variables and relating the social to the technical aspect.

SE addresses translation of stakeholder needs into system requirements and facilitates the process by which the specification of systems and/or components satisfies those requirements. Although programs differ in underlying requirements, SE provides a logical sequence of steps toward deriving good requirements and transforming them into solutions regardless of the program's size or complexity. These steps generate a series of work products that specify characteristics of systems (at any level), demonstrate and document the traceability to stakeholder needs (expressed or implied), and define how the requirements are validated and the systems (and associated components) are verified. To maximize effectiveness, SE commences before any significant product development activities and continues throughout the program's lifecycle. When performed correctly, SE helps to ensure that program execution is right from the start. If problems are encountered, they are detected and resolved early. This process reduces program cost and risk.

1.1 Purpose

The four primary purposes of this manual are to:

- Define the FAA's integrated practice of SE to be used by any engineer or group performing a task requiring an SE approach; by design, this practice is compatible with all components of the agency and consistent with sound government and industry best policies and guidelines
- Provide methods and tools that result in effective and consistent SE
- Supply detailed information on work products of SE activities that are needed to ensure uniform and consistent high-quality products Enable
- SE to participate in and support Program Management needs
- Enable SE to participate in and support Program Management

1.2 Scope

The SEM describes 12 major SE elements as they are applied within the FAA. The SEM supports the Acquisition Management System (AMS) by identifying the proper application of SE elements in the AMS decision and acquisition processes. Figure 1.2-1 shows the 12 SE elements.

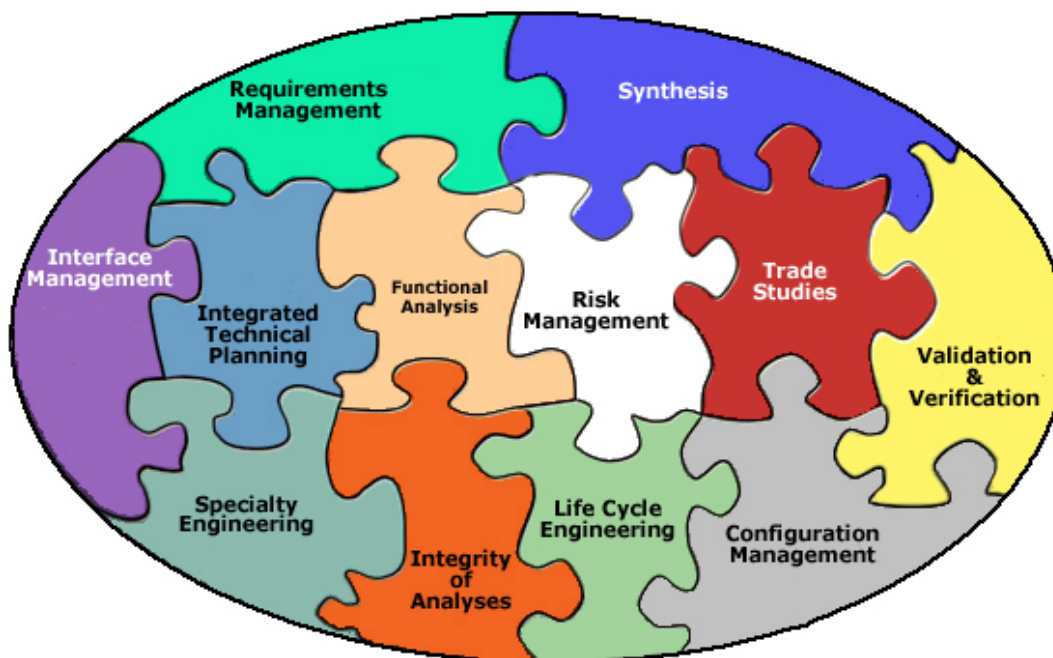


Figure 1.2-1. Federal Aviation Administration System Engineering Elements

As a how-to manual for SE, the SEM defines the constituent SE elements to be performed throughout the program lifecycle. The term “program” is intended to mean projects of all sizes and complexity, ranging from the NAS to individual parts. While the SEM is primarily directed at NAS modernization, it is recommended that individual programs tailor the application of processes, tools, and techniques according to program requirements. Further, implementation of these processes are to be directed by the appropriate SE management authority designated in the NAS System Engineering Management Plan (SEMP) or, on a given program, by the Chief System Engineer or Program Manager. This manual includes guidance on tailoring (see Section 3.6).

The SEM defines the FAA SE elements as well as the work products generated from each SE element. The 12 elements appear in Table 1.2-1 along with each element’s purpose or function. A 13th element listed provides for process management and maintenance of the other 12 elements.

Table 1.2-1. System Engineering Elements

System Engineering Element	Purpose of Element
Integrated Technical Planning	Plans the SE efforts and products.
Requirements Management	Identifies and manages the requirements that describe the desired characteristics of the system.
Functional Analysis	Describes the functional characteristics (what the system needs to do) that are used to derive requirements.
Synthesis	Transforms requirements into physical solutions.
Trade Studies	Assists decisionmaking by analyzing and selecting the best-balanced solutions to requirements.
Interface Management	Identifies and manages the interactions between segments within a system or interactions with other peer systems.
Specialty Engineering	Analyzes the system, requirements, functions, solutions, and/or interfaces using specialized skills and tools. Assists in the derivation of requirements, synthesis of solutions, selection of alternatives, and validation and verification of requirements.
Integrity of Analyses	Ensures that the analyses provide the required level of fidelity and accuracy.
Risk Management	Identifies, analyzes, and manages the uncertainties of achieving program requirements by developing strategies to reduce the severity or likelihood of those uncertainties.
Configuration Management	Establishes and maintains consistency and manages change in the system performance, functional, and physical attributes.
Validation and Verification	Determines if system requirements are correct. Determines that the solution meets the validated requirements.
Lifecycle Engineering	Identifies and manages requirements for system lifecycle attributes, including real estate management, deployment and transition, integrated logistics support, sustainment/technology evolution, and disposal.
System Engineering Process Management	Manages and maintains SE processes to meet FAA goals. Gains agencywide skill and standardization by continuously improving the effectiveness and efficiency of SE processes and tools.

1.3 Organization of the Manual

Chapter 1 contains the Purpose, Scope, Manual Organization, Relationship Between the SEM and the SEMP, System Engineering Process Descriptions, and Process-Based Management and System Engineering. The historical background and context for the SE practice appear in Chapter 2. Chapter 3 provides a fairly high-level description of the relationship between this manual and each phase of the FAA AMS. A detailed discussion of each of the major SE elements and their interrelationships appears in Chapter 4. Also included is a correlation between each of the SE elements (with its associated Chapter 4 paragraph number) and the reference to the associated section of the integrated Capability Maturity Model (iCMM) (e.g., SEM 4.12; iCMM PA 08).

The following appendices are included:

- Acronyms
- Glossary
- Initial System Requirements Review Checklist
- Concerns and Issues
- Integrated Technical Planning Details
- AMS Lifecycle Phase and Associated SE Element Work Products

1.4 Relationship Between the SEM and the SEMP

The SEM and SEMP are designed to work together. The SEM answers SE questions related to what and how, while the SEMP answers SE questions related to what, who, when, and why (i.e., why a particular organization or program is implementing or not implementing a particular SE element versus the SEM's discussion regarding a SE element's purpose). The "what" or products and activities of SE directly connect them. This relationship between the SEM and SEMP appears in Figure 1.4-1

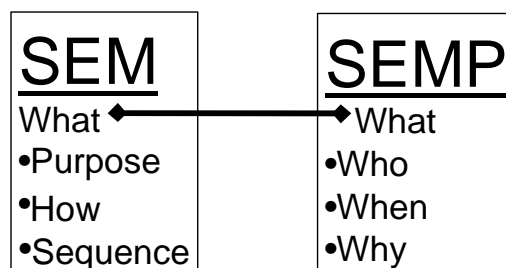


Figure 1.4-1. Relationship Between the System Engineering Manual and the System Engineering Management Plan

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95 1.5 System Engineering Process Descriptions

96 The SE process descriptions in Chapter 4 include the following information:

- 97 • **Process Definition.** Included are the purpose for carrying out the specific SE process
98 and a narrative description of the specific SE process. This narrative discusses the
99 function for the process (what to do). Program implementers may use this information to
100 tailor specific activities to align them with the development events of the program.
- 101 • **Process-Based Management (PBM) Charts.** Each SE element section in Chapter 4
102 contains a standard template that uses PBM charts to describe the SE element process.
103 The templates indicate the major steps of the SE process, inputs to the process and
104 associated providers, possible outputs generated, and associated product customers
105 (from an SE view). The SEM also identifies the supplying (inputs) and using (outputs)
106 processes that are used during process implementation to establish necessary program
107 communication, documentation, and review activities.

108
109 The granularity of products, both input and output, depends on the phase of the AMS lifecycle to
110 which the particular SE element being discussed is applied. For example, synthesis
111 results in much greater solution development than during Mission Analysis.

112
113 The process descriptions consist of all aspects of each SE process, including the need to
114 design for safety as well as for affordability, performance, usability, operational suitability, and
115 cost of ownership. On some programs, a given activity may be performed informally (e.g., in an
116 engineer's notebook) or formally, with interim products under formal baseline control.

117 Each SE process includes these major workflow tasks, which are also shown in PBM chart
118 form.

- 119 • **How To Do It.** The SEM discusses specific approaches or techniques for implementing
120 each SE process and provides guidance for selecting the right approach for a given
121 program phase. It summarizes the key points, focusing on the what and why as well as
122 the how.
- 123 • **Inputs.** This category includes information from external sources or other processes
124 that initiates the process or is received during the conduct of the process.
- 125 • **Outputs.** This category includes information developed during and by the conduct of
126 the process.
- 127 • **Entrance Criteria.** This category is what is required to start the process.
- 128 • **Exit Criteria.** This category includes the set of activities and products that are to be
129 completed by the end of the process.
- 130 • **Metrics.** This category includes examples of metrics for measuring the level of
131 performance for the process, as well as the work products generated by the process.

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- **Methods/Tools.** This category includes specific tools or methods that are necessary (or desirable) to efficiently implement the process as described. They also let the user know what is available within the AMS FAA Acquisition System Toolset (<http://fast.faa.gov/>).
- **Examples.** This category includes examples of both SE work products and the standard templates for producing the SE work products. Examples may be contained either within a particular section of Chapter 4, an appendix to the SEM, or on the FAA's intranet, in which case a reference uniform resource locator (URL) is provided.
- **References.** This category includes documents from the government, industry, and academia that cover relevant topics regarding that section.

1.6 Process-Based Management and System Engineering

It is very difficult to develop a generic, top-level process model that reflects all interactions among the processes for the SE elements shown earlier in Table 1.2-1. The interactions and iterations between the SE elements may be different depending on the program under consideration. Chapter 3 contains a definition of the SE element interaction for each of the major phases of the AMS (i.e., Mission Analysis, Investment Analysis, Solution Implementation, In-service Management, and Disposal). In addition, Figure 3.1-1, System Engineering Functional N² Diagram, contains an N² diagram that depicts the interrelationships, inputs, outputs, and products from the related processes. As stated above, Chapter 4 contains a standard template that uses PBM charts to describe the SE element process.

2 OVERVIEW OF SYSTEM ENGINEERING

This section traces several key developments and lessons learned that led to today's championing of SE as a powerful approach to organizing and conducting complex programs, such as those found in the NAS. SE continues to evolve, with an emphasis on stronger commercial- and team-based engineering organizations, as well as organizations without technical products. Before World War II, architects and civil engineers were, in effect, system engineers who worked on large, primarily civil, engineering projects, including the Egyptian pyramids, Roman aqueducts, Hoover Dam, the Golden Gate Bridge, and the Empire State Building, while other architects worked on trains and large ships. However, "early" system engineers operated without any theory or science to support SE. Thus, they lacked defined and consistently applied processes or practices. During World War II, a program manager and chief engineer might oversee development of an aircraft program, while others managed key subsystems, such as propulsion, controls, structure, and support systems, leading to a lack of uniformity throughout the process.

Some additional SE elements, such as operations research and decision analysis, gained prominence during and after World War II. Today, with more complex requirements and systems, chief engineers use SE to develop requirements and to integrate the activities of the program teams.

SE began to evolve as a branch of engineering during the late 1950s. At this time—when both the race to space and the race to develop missiles equipped with nuclear warheads were considered absolutely essential for national survival—the military services and their civilian contractors were under extreme pressure to develop, test, and place in operation nuclear-tipped missiles and orbiting satellites. In this climate, the services and their contractors sought tools and techniques to improve system performance (mission success) and program management (technical performance, delivery schedule, and cost control). Engineering management evolved, standardizing the use of specifications, interface documents, design reviews, and formal configuration management. The advent of hybrid and digital computers permitted extensive simulation and evaluation of systems, subsystems, and components that facilitated accurate synthesis and tradeoff of system elements.

The lessons learned with development programs led to innovative practices in all phases of high-technology product development. A driving force for these innovations was attainment of high-system reliability. Some examples of changes introduced during the period are:

- Parts traceability
- Materials and process control
- Change control
- Product accountability
- Formal interface control
- Requirements traceability

2.1 What Is System Engineering?

Beyond the definition used in the Introduction (Chapter 1), SE is an overarching process that trades off and integrates elements within a system's design to achieve the best overall product and/or capability known as a system. Although there are some important aspects of program management in SE, it is still much more of an engineering discipline than a management discipline. SE requires quantitative and qualitative decisionmaking involving tradeoffs, optimization, selection, and integration of the results from many engineering disciplines.

SE is iterative—it derives and defines requirements at each level of the system, beginning at the top (the NAS level) and propagating those requirements through a series of steps that eventually leads to a physical design at all levels (i.e., from the system to its parts). Iteration and design refinement lead successively to preliminary design, detail design, and final approved design. At each successive level, there are supporting lower-level design iterations that are necessary to gain confidence for decisions. During these iterations, many concept alternatives are postulated, analyzed, and evaluated in trade studies. These iterative activities result in a multi-tier set of requirements. These requirements form the basis for structured verification of performance. SE closely monitors all development activities and integrates the results to provide the best solution at all system levels.

2.2 What Is a System?

A system is an integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. These integrated parts include people, hardware, software, firmware, information, procedures, facilities, services, and other support facets. People from different disciplines and product areas have different perspectives on what makes up a system. For example, software engineers often refer to an integrated set of computer modules as a system. Electrical engineers might refer to a system as complex integrated circuits or an integrated set of electrical units. The FAA has an overarching system of systems called the NAS that includes, but is not limited to, all the airports; aircraft; people; procedures; airspace; communications, navigation, and surveillance/air traffic management systems; and facilities.

At times, it is difficult to agree on what comprises a system, as it depends entirely on the focus of those who define the objective or function of the system. For example, if the objective is to print input data, a printer may be defined as the system. However, another might consider the electricity required for the printer. Expanding the objective to processing input data and displaying the results yields a computer as the system. Further expansion of the objective to include a capability for computing nationwide or worldwide data and merging data/results into a database results in a computing network as the system, with the computer and printer(s) as subsystems of the system.

SE first defines the system at the top level, ensuring focus and optimization at that level, thus precluding narrow focus and suboptimization. It then proceeds to increasingly detailed lower levels until the system is completely decomposed to its basic elements. This hierarchy is described in the following paragraph.

2.2.1 System Hierarchy

A system may include hardware, software, firmware, people, information, techniques, facilities, services, and other support items. Figure 2.2-1 establishes a common reference for discussing

the hierarchy of a system/subsystem within the NAS. Each system item may have its own associated hierarchy. For example, the various software programs/components that may reside in a system have a commonly accepted hierarchy as depicted in Figure 2.2-2. Thus, Figure 2.2-2 is a subset of Figure 2.2-1 in that a system/subsystem may have multiple Computer Software Configuration Items. The depths of this common hierarchy may be adjusted to fit the complexity of the system. Simple systems may have fewer levels in the hierarchy than complex systems and vice versa. Because there may be varying hierarchal models referenced in the realm of SE, it is important for those who define the objective or function of a given system/subsystem to also lay out the hierarchal levels of the system in order to define the system's scope.

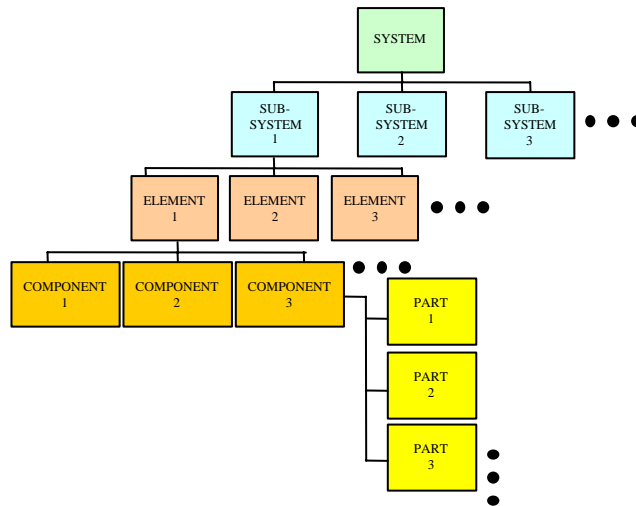


Figure 2.2-1. System Hierarchy

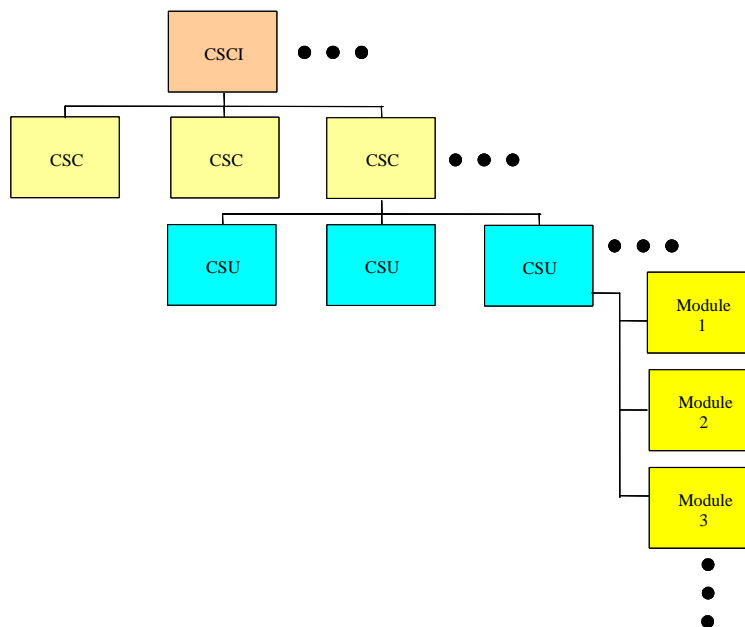


Figure 2.2-2. Common Software Hierarchy

Succeeding levels with the system/subsystem hierarchy are defined below:

- **System.** An integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. These parts include people, hardware, software, firmware, information, procedures, facilities, services, and other support facets.
- **Subsystem.** A system in and of itself (reference the system definition) contained within a higher-level system. The functionality of a subsystem contributes to the overall functionality of the higher-level system. The scope of a subsystem's functionality is less than the scope of functionality contained in the higher-level system.
- **Element.** An integrated set of components that comprise a defined part of a subsystem (e.g., the fuel injection element of the propulsion subsystem).
- **Component.** Composed of multiple parts; a clearly identified part of the product being designed or produced.
- **Part.** The lowest level of separately identifiable items within a system.
- **Software.** A combination of associated computer instructions and computer data definitions required to enable the computer hardware to perform computational or control functions.
- **Computer Software Configuration Item (CSCI).** An aggregation of software that is designed for configuration management and treated as a single entity in the Configuration Management process (Section 4.11).
- **Computer Software Component (CSC).** A functionally or logically distinct part of a CSCI, typically an aggregate of two or more software units.
- **Computer Software Unit.** An element specified in the design of a CSC that is separately testable or able to be compiled.
- **Module.** A program unit that is discrete and identifiable with respect to compiling, combining with other units, and loading.

2.3 Why Use System Engineering?

The need for effective SE is most apparent with large, complex system developments, such as weapons and transportation systems. However, SE is also important in developing, producing, deploying, and supporting much smaller systems, such as cameras and printers. The growing complexity in development areas has increased the need for effective SE. For example, about 35 years ago in the semiconductor industry, a single chip was no more complex than a series of a few gates or, at most, a four-stage register. Today, Intel's Pentium processor is far more complex, which immensely expands the application horizon but demands far more sophisticated analysis and discipline in design.

The movement to concurrent engineering as the technique for performing engineering development is actually performing good SE. SE provides the technical planning and control mechanisms to ensure that the activities/results of concurrent engineering meet overall system requirements.

A driving principle for SE is the teaming that often occurs during development programs. In this case, teaming is among several entities that may have different tools, analysis capabilities, and

302 so on. SE principles defined in this manual may provide an improved ability to plan and control
303 activities that require interaction and interfacing across boundaries.

304 The strongest argument for using the SE processes is that they increase the likelihood that
305 needs may be fully and consistently met in the final product.

3 SYSTEM ENGINEERING IN THE ACQUISITION MANAGEMENT SYSTEM PROGRAM LIFECYCLE

3.1 Introduction

This chapter discusses the relationship between the SE elements and their association with the phases of the AMS. The products generated by each of the SE elements and the inputs to and outputs from these elements are described for each AMS phase, and the elements are associated with the JRC decision points.

This SEM reflects the recently approved SE standards, methodologies, and processes. It recognizes that the current state of the referenced AMS, SE documents, and processes herein may not currently be in total agreement because that documentation and the SEM are in different update cycles.

The inputs, SE activities, and outputs of each of the AMS phases appear graphically. Also, included is a section to provide guidance on tailoring the SE process to a particular program.

3.1.1 Relationship Between the System Engineering Elements

Chapter 1 (see Table 1.2-1) lists the SE elements. This section discusses the relationships between the SE elements by portraying the inputs to and the outputs from the various elements. This approach describing these interrelationships uses an N^2 diagram for the SE elements. The SE elements are arrayed along the diagonal in Figure 3.1-1. The interpretation of the N^2 diagram is to take the intersection of the rows and columns interconnecting any two elements and reading the contents of those blocks. The information contained therein indicates the interface between the elements in the form of inputs, outputs, and products.

3.1.2 Relationship of the System Engineering Elements to the Acquisition Management System Program Lifecycle

The program lifecycle includes all activities and products associated with a system, from initial concept to disposal and elimination. This falls in line with the global aspects of SE's definition. Definitions of the program lifecycle phases serve different purposes for different SE elements. It is recommended that System sponsors and high-level management executives use these phases and their associated milestones (e.g., Mission Need Decision (MND), Initial and Final Investment Decisions, and In-Service Decision) to determine whether to continue or terminate the endeavor. Thus, it is recommended that the phases be used to measure a program's progress and develop input to the Joint Resources Council (JRC), which ultimately makes the noted decisions.

EXTERNAL	FAA Policy Integrated Program Schedule Corporate Strategy and Goals	Constraints FAA Management Decisions Govt & Intl Regulations & Statutes Legacy System Stakeholder Needs Standards Technology	FAA Management Decisions Legacy System	Constraints Legacy System Market Research Standards Technology	Market Research Technology Constraints Integrated Program Schedule	FAA Policy Legacy System Standards Interface Change Request	FAA Policy Standards	Technology Constraints	External Environmental Forces Constraints Technology Concerns/Issues Integrated Program Schedule	FAA Policy	Need Standards	Technology Test & Assessment Articles	Constraints External Environmental Forces Govt & Intl Regulations & Statutes Market Research FAA Policy Technology Concerns/Issues Integrated Program Schedule	
Integrated Program Plan	INTEGRATED TECHNICAL PLANNING	Integrated Lifecycle Plan Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan SEMP	Integrated Program Plan SEMP	Constraints Integrated Logistics Support Plan Integrated Program Plan SEMP	Integrated Program Plan NAS Architecture SEMP	Integrated Lifecycle Plan Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan SEMP	Concerns/Issues Integrated Program Plan SEMP	Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan Master Verification Plan NAS Architecture SEMP	Integrated Lifecycle Plan Integrated Program Plan NAS Architecture SEMP	
Requirements RVCD		REQUIREMENTS MANAGEMENT	Mission Need Statement Requirements	Requirements RVCD	Constraints Requirements	Requirements Mission Need Statement	Requirements RVCD	Requirements Tools/Analysis Requirements	Requirements RVCD Concerns/Issues	Requirements	Requirements	Requirements VRTM	Mission Need Statement Requirements	
	Concept of Operations NAS CONOPS Planning Criteria	Concept of Operations Functional Architecture OSED	FUNCTIONAL ANALYSIS	Functional Architecture OSED	Constraints Functional Architecture OSED	Concept of Operations Functional Architecture OSED	Concept of Operations Functional Architecture OSED	Tools/Analysis Requirement	Concerns/Issues	Functional Architecture OSED	Concept of Operations Functional Architecture OSED	Functional Architecture	OSED	
	Planning Criteria	Constraints Requirements Physical Architecture	Physical Architecture	SYNTHESIS	Physical Architecture Design Constraint Constraints Description of Alternatives	Operational Concept Dem Physical Architecture	Description of Alternative Physical Architecture	Tools/Analysis Requirements	Concerns/Issues	Configuration Description	Operational Concept Dem Physical Architecture	Physical Architecture	Design Constraint Operational Concept Demo	
Trade Study Reports	Planning Criteria	Trade Study Reports		Trade Study Reports	TRADE STUDIES	Trade Study Reports		Tools/Analysis Requirements	Concerns/Issues				Trade Study Reports	
	Planning Criteria	Interface Control Documents Interface Requirements Documents	Interface Control Documents	Interface Requirements Documents	Constraints	INTERFACE MANAGEMENT	Interface Control Documents		Concerns/Issues	Interface Revision Proposal Interface Requirements Documents Interface Control Documents	Interface Requirements Documents	Interface Control Documents		
Certification Package	Planning Criteria	Design Analysis Reports Requirements	Design Analysis Reports	Design Analysis Reports	Design Analysis Report Constraints	Design Analysis Reports	SPECIALTY ENGINEERING	Design Analysis Reports Tools/Analysis Requirements	Concerns/Issues Design Analysis Reports		Demonstrations Design Analysis Reports	Demonstrations Verification Criteria Design Analysis Reports	Design Analysis Reports	
Credible Analysis Results	Analysis Criteria Planning Criteria	Analysis Criteria	Analysis Criteria	Analysis Criteria	Analysis Criteria Constraints		Analysis Criteria	INTEGRITY OF ANALYSES	Concerns/Issues Analysis Criteria	Credible Analysis Results		Analysis Criteria	Analysis Criteria	
Program Risk Register Program Risk Summary Risk Mitigation Plan Summary Risk Mitigation Plans	Planning Criteria	Risk Mitigation Plans		Risk Mitigation Plans	Constraints			Tools/Analysis Requirements	RISK MANAGEMENT					
	Planning Criteria	Approved Baseline Changes Configuration Status Report Updated Baselines		Configuration Status Report Updated Baselines Approved Baseline Changes	Constraints		Baselines	Baselines	Baselines Concerns/Issues	CONFIGURATION MANAGEMENT		Validation Reports Updated Baselines Configuration Status Report Approved Baseline Changes	Updated Baselines Configuration Status Report Approved Baseline Changes	
	Planning Criteria	Validation Reports	Validated Need		Constraints		Validation Reports		Concerns/Issues		VALIDATION			
	Planning Criteria	RVCD VRTM			Constraints			Tools/Analysis Requirements	Concerns/Issues			VERIFICATION		
	Planning Criteria				Lifecycle Cost Estimate Constraints			Tools/Analysis Requirements	Concerns/Issues Constraints				LIFE CYCLE ENGINEERING	
NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	Maintain SE Process

Figure 3.1-1 System Engineering Functional N2 Diagram

Each program decision milestone is associated with a review. The reviews and milestones are:

- **JRC 1/MND milestone.** During the mission analysis phase, an Investment Analysis Readiness Review (IARR) is conducted just prior to the JRC 1 MND milestone. An IARR briefing is presented to the Federal Acquisition Executive (FAE) and the sponsors for approval. Following the successful approval of the IARR, a briefing for review by the JRC is conducted before the MND.
- **JRC 2a/Initial Investment Decision milestone.** A briefing for review by the JRC is conducted before the Initial Investment Decision.
- **JRC 2b/Final Investment Decision milestone.** During the final Investment Analysis (IA) stage of the IA phase, an optional Initial System Requirements Review (ISRR) may be conducted a couple of months prior to the Final Investment Decision Milestone. A briefing for review by the JRC is conducted before the Final Investment Decision.
- **JRC 3/In-Service Decision milestone.** The In-service Review checklist is reviewed and a briefing for review by the appointed decision authority is conducted before the In-Service Decision.

3.2 Systems Engineering Elements and the AMS

Following are the FAA SE elements associated with each of the AMS phases (Figure 3.2-1).

Mission Analysis

Integrated Technical Planning
Requirements Management
Functional Analysis
Synthesis
Interface Management
Specialty Engineering
Integrity of Analyses
Validation
Lifecycle Engineering

Investment Analysis

Integrated Technical Planning
Requirements Management
Functional Analysis
Synthesis
Trade Studies
Interface Management
Specialty Engineering
Integrity of Analyses
Risk Management
Validation
Lifecycle Engineering

Solution Implementation

Integrated Technical Planning
Requirements Management
Functional Analysis
Synthesis
Trade Studies
Interface Management
Specialty Engineering
Integrity of Analyses
Risk Management
Configuration Management
Verification
Lifecycle Engineering

In- Service Management

Integrated Technical Planning
Requirements Management
Functional Analysis
Synthesis
Trade Studies
Interface Management
Specialty Engineering
Integrity of Analyses
Risk Management
Configuration Management
Verification
Lifecycle Engineering

Figure 3.2-1. AMS Program Phase and Associated SE Elements

3.3 AMS/System Engineering Work Products Inputs and Outputs

To introduce the system engineering inputs, outputs, and work products associated with system engineering activities during each phase of the AMS, Table 3.3-1 contains a legend for the AMS phase inputs and outputs and developmental status of the work products and documents.

Table 3.3-1. Legend for AMS/System Engineering Work Products Inputs and Outputs for AMS Phases

Abbreviation		Meaning
C	=	Conceptual draft (precedes initial draft): The general notion and structure of the document has been created with minimal content.
I	=	Initial draft: The document has been populated with the majority of required content, but it still requires review for accuracy of information.
F	=	Final draft: The document is complete, accurate, and awaiting signature.
SD	=	Sustaining Document: For work products that are formal documents, the documents are sustained in the given phase. For work products that are not formal documents, the products are introduced, further developed, or sustained in the given phase.
SE	=	System Engineering

3.3.1 Associating System Engineering Work Products Inputs and Outputs With AMS Phases

The following sections of Chapter 3 associate the SE activities with each phase of the AMS lifecycle. Data Flow Diagrams highlight the SE processes and work products that are predominant during the associated AMS phase. In addition, a table is included that:

- Identifies the SE work products that are inputs and/or outputs to/from each of the AMS phases
- Identifies work products generated from processes external to SE that are necessary to initiate SE activities within the given phase

Table 3.3-2 is a high-level view of the various SE inputs, outputs, and work products and the AMS phases during which it is recommended that they be developed.

Table 3.3-2. AMS/System Engineering Work Products Inputs and Outputs for AMS Phases

AMS/SE INPUT, OUTPUT, OR WORK PRODUCT	JRC 1	JRC 2a	ISRR	JRC 2b	JRC 3
Acquisition Program Baseline (APB)		I	SD	F	SD
Analysis Criteria	I	F	SD	SD	SD
Approved Baseline Changes					SD
Certification Package				I	F
Concept of Operations (CONOPS)	F	SD	SD	SD	SD
Concerns/Issues	SD	SD	SD	SD	SD
Configuration Description		I		F	
Configuration Status Report		SD	SD	SD	SD
Constraints	SD	SD	SD	SD	SD
Corporate Strategy and Goals	SD	SD	SD	SD	SD
Credible Analysis Results	SD	SD	SD	SD	SD
Demonstrations		SD	SD	SD	SD
Description of Alternatives	I	F			
Design Analysis Reports (DAR)	SD	SD	SD	SD	SD
Design Constraint	SD	SD	SD	SD	SD
External Environmental Forces	SD	SD	SD	SD	SD
FAA Management Decisions	SD	SD	SD	SD	SD
FAA Policy	SD	SD	SD	SD	SD
Functional Architecture	I	F ¹	SD	SD	SD
Functional Specification (i.e., E-spec.)		I		F	
Government and International Regulations and Statutes	SD	SD	SD	SD	SD
Integrated Lifecycle Plan		I		F	SD
Integrated Program Plan (IPP)		I		F	SD
Integrated Program Schedule		I		F	SD
Interface Change Request					SD
Interface Control Documents (ICD)				I	F
Interface Requirements Documents (IRD)		I		F	
Interface Revision Proposal				SD	SD
Investment Analysis Plan	I	F			
Investment Analysis Readiness Review	F				
Legacy System	SD	SD	SD	SD	SD
Lifecycle Cost Estimate	I			F	
Market Research	SD	SD	SD	SD	
Master Verification Plan (MVP)		I		F	SD
Mission Need Statement (MNS)	F	SD	SD	SD	SD
NAS Architecture	SD	SD	SD	SD	SD
NAS Concept of Operations (CONOPS)	SD	SD	SD	SD	SD
NAS System Engineering Management Plan	SD	SD	SD	SD	SD
Operational Concept Demonstrations		SD	SD	SD	

**Table 3.3-2. AMS/System Engineering Work Products Inputs and Outputs for AMS Phases
(Continued)**

AMS/SE INPUT, OUTPUT, OR WORK PRODUCT	JRC1	JRC2A	ISRR	JRC2B	JRC3
Operational Services and Environmental Description		I		F	
Physical Architecture	C	I		F	
Planning Criteria	SD	SD	SD	SD	SD
Program Risk Register		SD	SD	SD	SD
Program Risk Summary		SD	SD	SD	SD
Requirements	I	F ¹	SD	SD	SD
Requirements Verification Compliance Document (RVCD)		I		F	
Risk Mitigation Plan Summary	I	F	SD	SD	SD
Risk Mitigation Plans	I	F	SD	SD	SD
Stakeholder Needs	F	SD	SD	SD	SD
Standards	I	F	SD	SD	SD
Statement of Work		I		F	
System Engineering Management Plan (SEMP)		I		F	
Technology	SD	SD	SD	SD	SD
Test and Assessment Articles				I	F
Tools/Analysis Requirements		SD	SD	SD	SD
Trade Study Reports		SD	SD	SD	SD
Updated Baselines				SD	SD
Validated Need	I	F			
Validation Reports	SD	SD	SD	SD	SD
Verification Criteria	SD	SD	SD	SD	SD
Verification Requirements Traceability Matrix (VRTM)	C	I		F	SD
Work Breakdown Structure		I		F	
NOTE: 1. This does not imply that there is no further decomposition. For example, "Final" requirements at this point pertain to the final Requirements Document, yet further decomposition takes place to generate a functional specification (i.e., E-spec.).					

3.4 AMS Program Phase

3.4.1 Mission Analysis Phase

3.4.1.1 Mission Analysis Phase Objectives

The basic objectives of the Mission Analysis (MA) phase is to correctly identify a capability shortfall, quantify a need, and identify potential technological opportunities to begin to resolve that need. Nonmaterial solutions are also evaluated during this phase. In most cases, the MA consists of activities to validate high-level needs and to seek approval to proceed to the Investment Analysis phase. It has two dimensions: a technical dimension and a program-

planning dimension. The technical dimension is to ensure that a complete understanding of the demand for services has been identified and quantified. This is accompanied by identification and quantification of existing and projected supply of services. The program-planning dimension is to identify potential project-scope and estimated resource requirements. The primary outputs of this phase are the final Mission Need Statement (MNS), an initial Requirements Document (iRD), initial Alternatives, Concept of Use, and an Initial Investment Analysis Plan. The MA phase ends with an MND. Figure 3.4-1 is an overview of the primary SE activities that occur during MA.

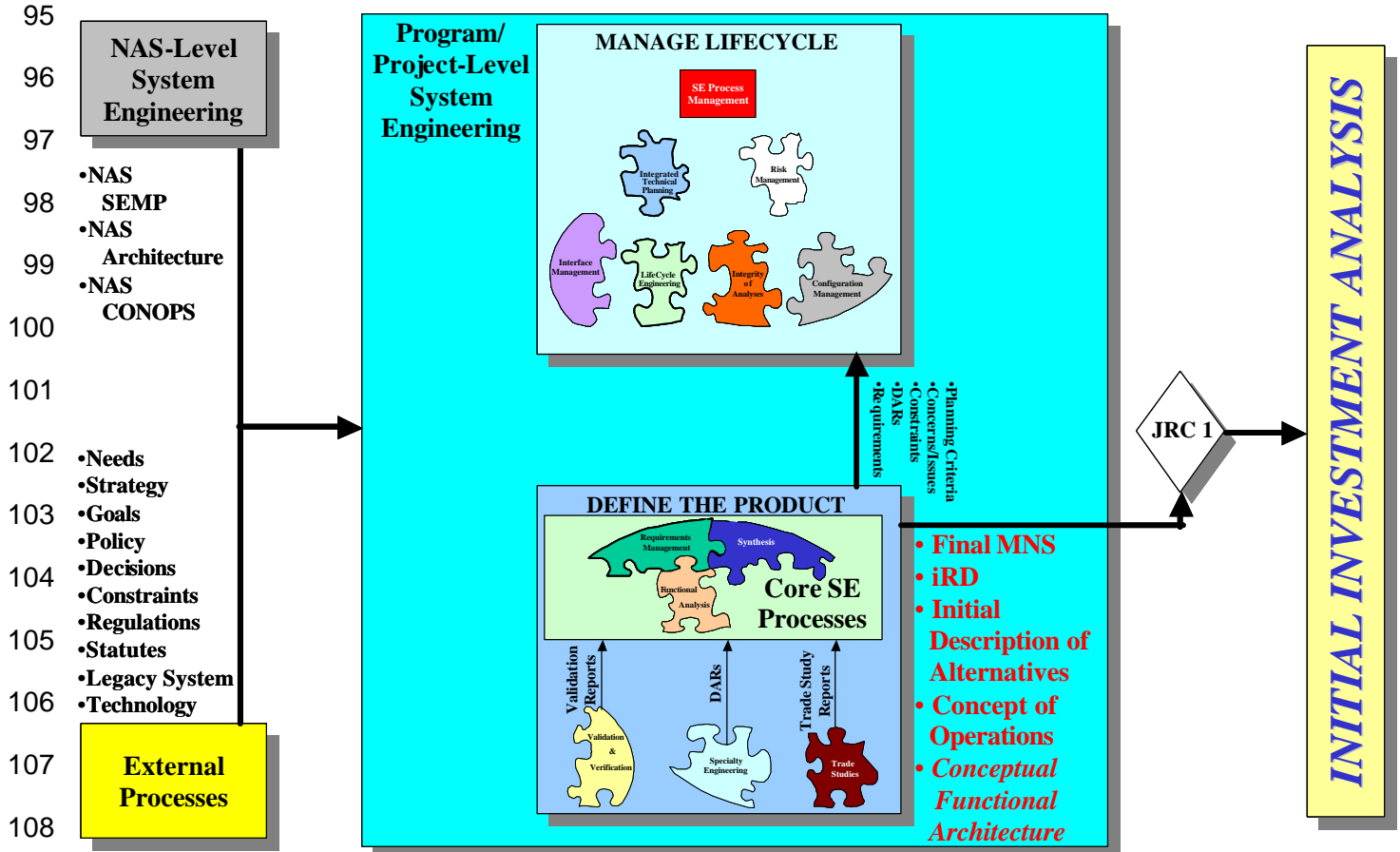


Figure 3.4-1 Mission Analysis System Engineering Inputs and Outputs

Table F-1, in Appendix F contains a legend for all of the SE Work Products and Inputs and Outputs for each AMS phase. Table F-2 in Appendix F lists the inputs and outputs for the MA phase and their association with that SE element that produces them.

3.4.1.2 Mission Analysis Inputs

The primary entrance criteria are the concept of a given “need” and approval to initiate SE efforts during the MA phase. Figure 3.4-1 shows the external processes that occur and influence the origination of a particular MA. But the two most important inputs are the

recognized “need” and the decision to proceed. The column labeled “JRC 1” in Table 3.3-2 contains the inputs and outputs and work products associated with the MA phase.

3.4.1.3 Mission Analysis System Engineering Activities

SE is initiated when a stakeholder need is recognized and is used to understand functionally what is required to meet the stated need. A system Concept of Operations (CONOPS) is developed via Functional Analysis (Section 4.4) and is used in Requirements Management (Section 4.3) to develop the MNS. The MNS is a primary SE output during the MA phase; it also drives the continued iterations of Functional Analysis and Requirements Management. The iRD is introduced here. The interaction of these two processes results in a high-level functional decomposition and, likewise, a high-level requirements decomposition. The resulting set of requirements is validated and is used, along with the high-level functional architecture, during the Synthesis process (Section 4.5) to develop a description of alternatives and associated design constraints. At this point in time, these alternatives and constraints are very high-level and are used as primary input into the IA phase to provide scope for the program. In addition to the core Functional Analysis, Requirements Management, and Synthesis activities, other SE processes are initiated during the MA phase. These activities involve technical planning to provide program management and guidance on planning both management and SE activities throughout the system’s lifecycle. This planning is required to provide proper guidance for SE activities, including identifying risks and plans to mitigate those risks and establishing analysis criteria for the various analyses that occur during system design. Any of the SE activities may surface concerns and issues to be processed by Risk Management (Section 4.10), as well as constraints to bound the activities of the Trade Studies process (Section 4.6) that occur during the follow-on phases.

Electronic Industries Alliance standard 731-2 defines a constraint as (1) a restriction, limit, or regulation or (2) a type of requirement that is not tradable against other requirements. Often, these are defined in work-scope statements given by project contributors during the cost definition process. This includes gathering stakeholder inputs on “needs,” system constraints (costs, technology limitations, and applicable specifications and legal requirements), and system “drivers” (such as competition capabilities and critical environments). It is recommended that tradeoffs be done on the desirability of including a performance capability in the system versus a more affordable (or less risky) system approach. This tradeoff process often begins well before a firm set of needs is established and continues throughout the MA phase in which stakeholder interaction on specific items proposed may take place. Constraints may be further adjusted throughout later AMS phases. Like behavior deficiencies or shortfalls, these are excellent opportunities for preplanned product improvement. Funding, personnel, facilities, manufacturing capability, critical resources, or other reasons may cause constraints. The reason for each constraint is readily understood.

Risk always is present in the lifecycle of both developed and commercial systems. The system may be intended for technical accomplishments near the limits of the state of the art, creating technical risk. System development may be rushed to deploy the system as soon as possible to meet an urgent need, leading to schedule risk. All systems are funding-limited, so cost risk is present. Risk may be introduced by external constraints or may develop from within the program, since technical risk may create schedule risk that in turn may create cost risk. It is recommended that each SE element active during this phase surface concerns and issues that present risk to the program.

163 When the JRC 1 meeting is being planned and the briefing being prepared, it is recommended
164 that each new initiative conduct an IARR. The FAE and sponsors conduct and approve the
165 IARR. Documentation available for this review consists of the following:

- 166 • Final MNS
- 167 • iRD
- 168 • Initial Alternatives
- 169 • Rough Order of Magnitude Life Cycle Cost
- 170 • Concept of Use
- 171 • Initial Investment Analysis Plan

172 **3.4.1.4 Mission Analysis Outputs**

173 It is recommended that the following criteria be met before the program enters the IA phase:

- 174 • Initial Description of Alternative Solutions
- 175 • Successful conduct and approval of the IARR
- 176 • Completion of all work products identified as MA outputs (see column labeled JRC 1 in
177 Table 3.3-2) to the version level specified

178 **3.4.2 Investment Analysis Phase**

179 **3.4.2.1 Investment Analysis Phase Objectives**

180 The IA phase of the AMS lifecycle has the following objectives:

- 181 • Further translate the final MNS and final Requirements Document (fRD) into lower-level
182 requirements and eventually into functional specifications
- 183 • Select the optimum solution
- 184 • Refine the optimum solution from a NAS perspective
- 185 • Modify the architecture to the recommended solution
- 186 • Complete the Acquisition Program Baseline (APB), Integrated Program Plan (IPP), and
187 all additional program plans
- 188 • Complete the functional architecture to a level appropriate to requirements (i.e., those
189 levels needed to support development of the fRD or system specification)

- List and analyze all programmatic risks
- Provide risk mitigation plans with associated costs

3.4.2.2 Investment Analysis Inputs

The IA phase of the AMS begins with approval of a mission need and iRD and ends with an Investment Decision. There are two stages during the IA phase: the initial IA stage (or the JRC 2a stage) and the final IA stage (or the JRC 2b stage). This section treats the IA phase as a whole, while subsequent sections describe the individual stages. Each stage is described later, along with its separate flow diagrams. Effectively, the outputs of the MA phase represent the inputs to the IA phase.

3.4.2.3 Investment Analysis System Engineering Activities

The core SE processes continue, in an iterative fashion, to produce a design that meets the stakeholder need. The SE elements involved during the IA phase are listed in Figure 3.2-1. Table 3.3-2 lists the AMS/SE work products inputs and outputs for each IA stage (see columns labeled JRC 2a and JRC 2b). Flow diagrams are included later for each IA stage in Figures 3.4-2 and 3.4-3, respectively. The Functional Analysis (Section 4.4) continues to decompose the functions to lower levels. These lower-level functions are used to develop more detailed requirements that are used to bound the next level of functional decomposition. The Specialty Engineering (Section 4.8) feeds this process by providing various Design Analysis Reports to further refine the requirements and manage various risk facets. Requirements generated from this interaction are then validated. Once validated, they are fed into the Synthesis process (Section 4.5), where alternative solutions to meet these requirements are developed and refined. The Trade Studies process (Section 4.6) and the Lifecycle Engineering process (Section 4.13) are both heavily employed during this phase to provide Synthesis in making an informed decision concerning the best solution set. The resulting physical architecture, in conjunction with the functional architecture, is used in Interface Management (Section 4.7) to develop Interface Requirements Documents (IRD) and eventually Interface Control Documents.

3.4.2.4 Investment Analysis Outputs

The primary outputs from the SE efforts in this phase are the functional and physical architectures and associated requirements in the form of IRDs and the fRD. The inputs, outputs, and work products associated with the SE elements that produce them, appear in Figure F-3 and F-4 of Appendix F. Table 3.3-2 showed the products, inputs and outputs required to complete the associated JRC milestones (i.e., initial IA for JRC 2a and final IA for JRC 2b).

3.4.2.5 Initial Investment Analysis Phase

3.4.2.5.1 Initial Investment Analysis Phase Objectives

The key ingredients of the Initial IA phase appear in Figure 3.4-2. The initial IA is the first of two stages in the IA phase. The main objective of this stage is to refine the set of alternative solutions developed during MA in response to the MNS and the requirements contained in the iRD. To accomplish this objective, SE analyzes the high-level requirements so that the needs, objectives, requirements, and operating scenarios are fully understood and integrated. Because these top-level requirements typically lack the details required to execute a design, it is

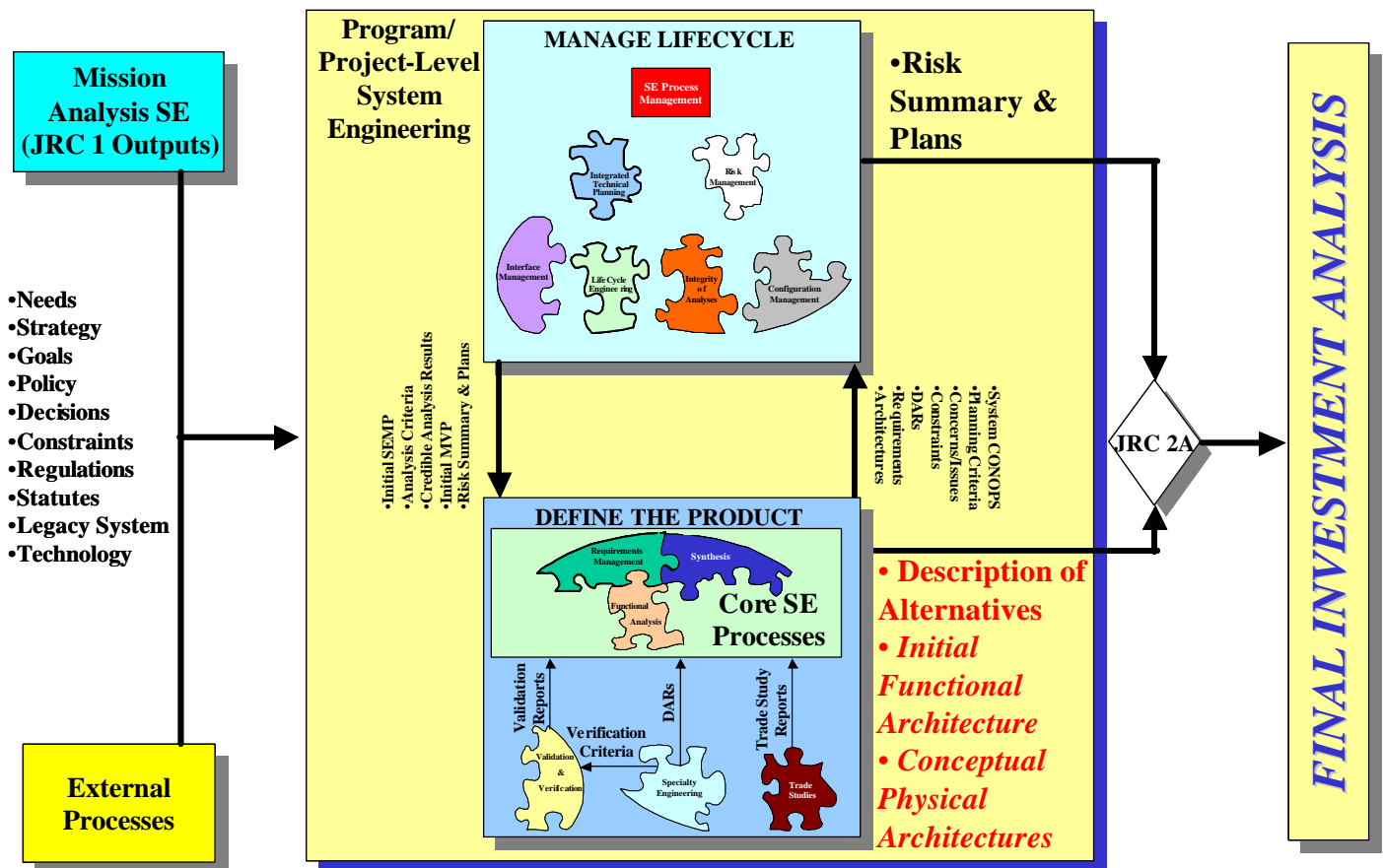


Figure 3.3-2 Initial Investment Analysis System Engineering Inputs and Outputs

important that stakeholders adequately communicate to eliminate gaps in understanding requirements. To this end, the needs, mission(s), and utilization environments are analyzed, interpreted, and coordinated with stakeholders to determine system requirements. This stage also identifies the required disciplines needed to support the effort as well as a review indicating that all stakeholders have been identified.

In this stage, the system functional architecture is expanded. The functions are then transformed into more detailed system requirements that are resolved in the system physical architectures. Higher-level requirements constrain the next lower functional architecture. In addition, the interfaces between the functions, subsystems, and elements that comprise the total system are documented. Functional and performance requirements are allocated to those subsystems and elements. Detailed subsystem and element requirements and constraints are developed, and subsystem and element concepts are traded and selected.

Further development and evaluation of alternative concepts pave the way for selection of the best concept. Each candidate concept is validated to ensure feasibility and that all requirements have been satisfied. Candidate alternative solutions that fail to meet requirements are modified or discarded. More detailed concept development and analyses are then

conducted to characterize each of the concepts to add maturity and facilitate selection of the best alternative. Trade Studies (Section 4.6) are conducted to select from alternative

approaches to satisfy requirements; identify preferred technologies and processes; define support concepts; assess lifecycle cost elements; and quantify program risks. Down-selection criteria are established based on design sensitivities, cost/benefit ratios, schedules, programmatic constraints and requirements, risks, corporate strategies, and other considerations, as applicable.

Of the set of viable alternatives, a single approach is selected before the close of this stage. The cost/benefit analysis that results in selection of the best concept is documented and made a part of the program documentation.

3.4.2.5.2 Initial Investment Analysis Inputs

These criteria include:

- An MND approving continuation of the program to the IA phase
- MA output, including an initial description of alternative solutions and an iRD
- Completion of all work products identified as MA outputs (see column labeled JRC 1 in Table 3.3-2) to the version level specified

Table F-3 in Appendix F lists the inputs and outputs for the Initial IA phase and associates them with the SE element that produces them.

3.4.2.5.3 Initial Investment Analysis System Engineering

In this stage of technical plans development, the following initial drafts of the IPP and the Integrated Lifecycle Plan are developed. In addition, the SEMP and Master Verification Plan (MVP) are created and developed to an initial draft state by the end of this stage. The iRD is developed to the fRD state. The IA process focuses on reviewing the CONOPS, refining the Operational System Environment Description from its initial draft, and further decomposing the next level of functions into sequenced and traceable functional architectures (dependent on the availability and detail of requirements documentation). During the initial IA, conceptual versions of the physical architectures for the set of alternatives are produced, and the description of alternatives are further refined. Activities during this phase include the design analysis of the benefits, strengths, and weaknesses of the alternative concepts against a common set of requirements and selection criteria to determine their relative merits. Design constraints are identified during this analysis. Concept demonstrations may also be conducted to support these activities. The draft IRD is developed during this phase to capture these interfaces. In addition to the tasks identified above, it is recommended that each SE element active during this phase surface concerns and issues that present risk to the program.

3.4.2.5.4 Initial Investment Analysis Outputs

Table 3.3-2 (JRC 2a column) contains the inputs and outputs and work products associated with the initial IA phase that are to be completed before the final IA phase. These outputs include the following:

- Solution selection has been made
- Authorization for the program to proceed to the final IA phase has been given

288 • All work products identified as initial IA outputs have been completed to the version level
289 specified

290 • Required disciplines have been identified

291 • Initial baseline planning has been completed

292 **3.4.2.6 Final Investment Analysis Phase**

293 **3.4.2.6.1 Final Investment Analysis Phase Objectives**

294 The key ingredients of the Final IA phase appear in Figure 3.4-3. The main objective of this
295 phase is to establish validated requirements, refine the final alternative solution, and document
296 the complete functional and programmatic baselines for that solution.

297 During the Final IA Phase, the SEM introduces a new, optional milestone that does not appear
298 in the current AMS. This milestone has been established to give management the option to
299 step back and review the progress of work activities and products that are to be completed by
300 the end of the final IA and before the JRC 2b review. This ISRR milestone, an optional point at
301 which to review program progress, may be added usually 1 to 2 months before JRC 2b. This is
302 not a mandatory AMS milestone, and the review is not conducted by the JRC, but may be used
303 primarily as a means to review and agree upon the final set of system requirements.

304 Table F-4 in Appendix F lists the inputs and outputs for the Final IA phase and associates them
305 with that SE element that produces the inputs and outputs.

306 **3.4.2.6.2 Final Investment Analysis Phase Inputs**

307 Prerequisites for entering the final IA phase include the following:

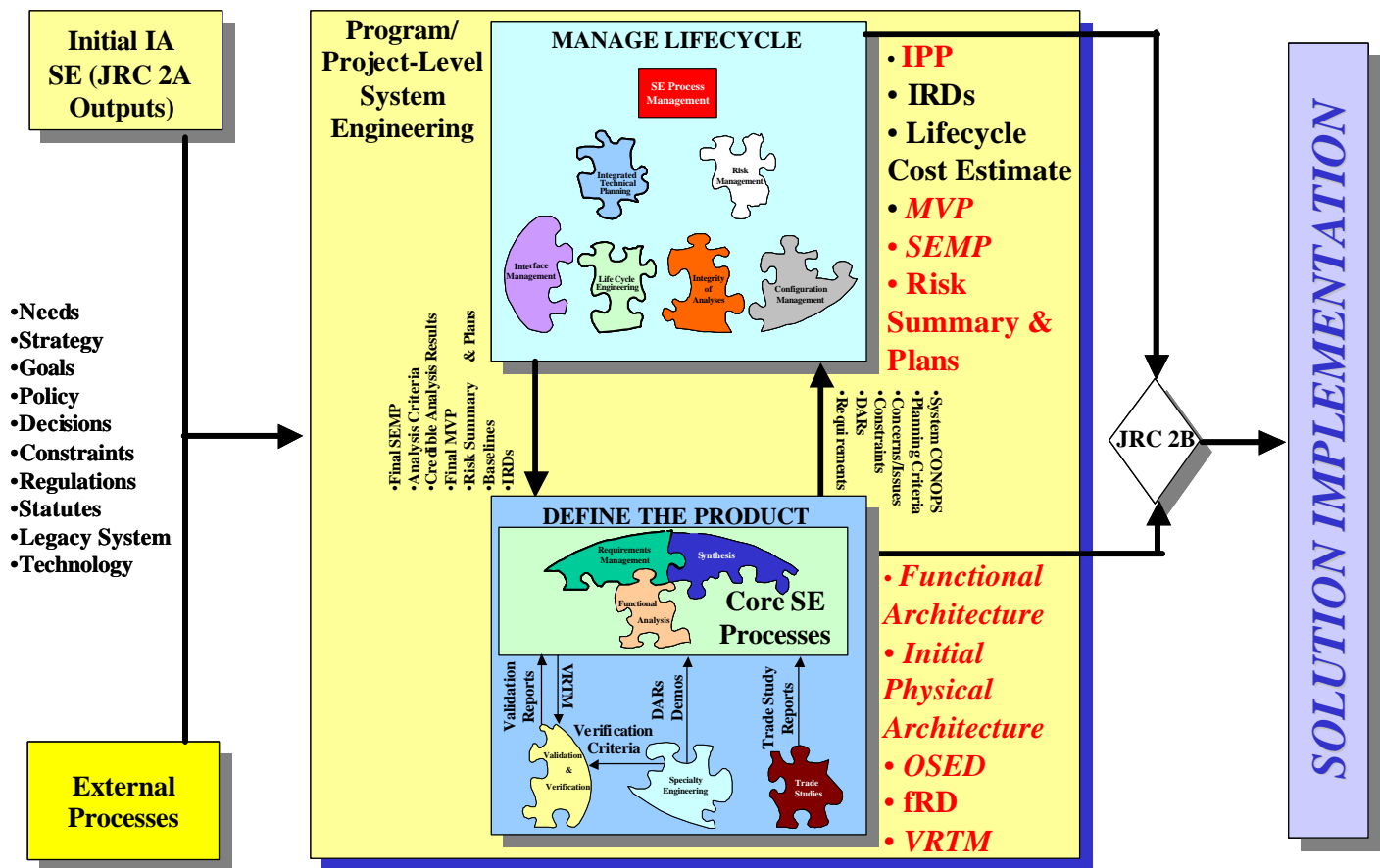
308 • The initial IA decision (JRC 2a) has been made, authorizing the program to proceed to
309 the final IA stage

310 • Work products from the initial IA stage have been completed to the version level
311 specified

312 • Solution selection has been made

313

314



9

Figure 3.4-3 Final Investment Analysis System Engineering Inputs/Outputs

Table 3.3-2 (column 2b) lists the inputs, outputs, and work products associated with the final IA.

3.4.2.6.2 Final Investment Analysis Systems Engineering

The final IA stage further refines the physical architecture and adds maturity to the documentation. The functional architecture is completed. Selected subsystem and element concepts are expanded with details to verify that they meet high-level requirements and constraints. The interfaces between the elements that comprise the subsystems are documented. Functional and performance requirements and constraints are allocated to those elements, and packages defining development of the elements are created.

A business case is developed that illustrates all stakeholder costs and obligations, providing details of both agency and nonagency resource demands. Program requirements are completed, corrected, and documented in the fRD. The fRD is reviewed at this time in preparation for the JRC 2b. In addition, the interfaces between the components that comprise the elements are documented, and functional and performance requirements are allocated to those components. The planned procurement specifications are listed and the APB is finalized. A successful IA leads to the JRC 2b decision for the program. All work products identified as

ISRR (if option is elected; see “ISRR” column in Table 3.3-2) outputs have been completed to the version level specified. If the option for the ISRR is elected, an ISRR checklist (see Appendix C) may be used in preparing for this review milestone.

3.4.2.6.3 Final Investment Analysis Outputs

The output criteria for the final IA phase include the following:

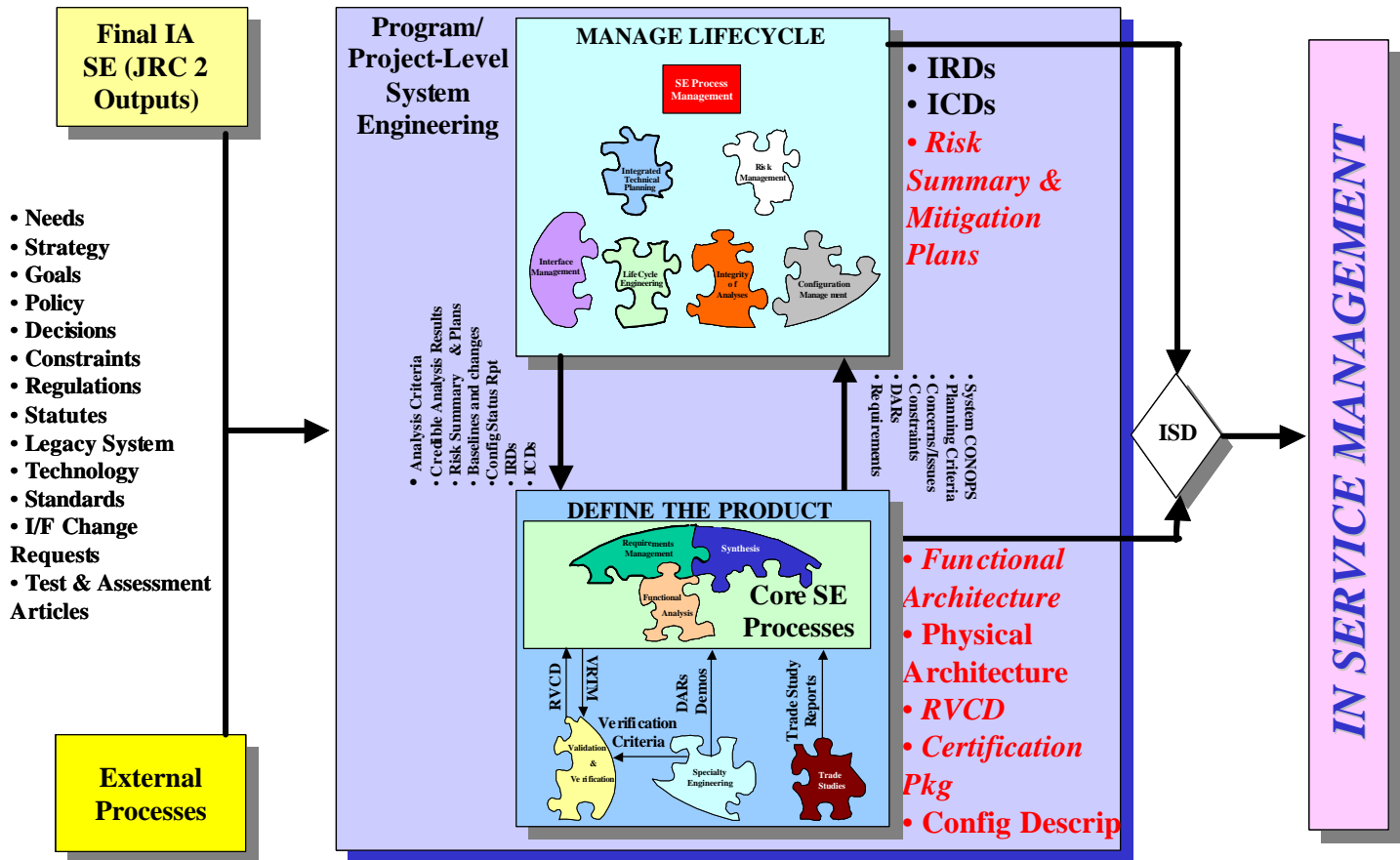
- All work products identified as final IA outputs have been completed to the version level specified
- The solution selected during the initial IA phase is defined via a physical architecture with assurance that it meets all system requirements
- The ISSR has been successfully completed if conducted
- If ISRR is conducted, all work products identified as ISRR outputs have been completed to the version level specified
- The final IA decision has been made, authorizing the program to continue into the Solution Implementation (SI) phase

3.4.3 Solution Implementation Phase

3.4.3.1 Solution Implementation Phase Objectives

As shown in Figure 3.4-4, the SI phase begins with the final IA decision at JRC 2b where an acquisition program is established for the solution selected and ends when the new capability goes into service. The flow diagram in Figure 3.4-4 shows the high-level SE inputs and outputs associated with the solution implementation phase. Table 3.3-2 (column labeled JRC 3) contains a more complete listing of all of the inputs, outputs, and work products associated with the AMS milestone JRC 3.

355



356

Note: Table 3.3-2 contains acronyms used here.

357

Figure 3.4-4 Solution Implementation System Engineering Inputs and Outputs

358

The SE activities conducted during SI vary widely, depending on the nature and scope of the acquisition program. For example, the activities associated with buying and deploying a commercial product typically are much less complex and time-consuming than those for a product requiring full development. However, in each case, it is recommended that products be able to meet stakeholder requirements, be operationally suitable, and compatible with other operational systems within the NAS before the decision is made to place it in service. The main objective of this phase is to successfully complete the necessary actions and activities to obtain the solution and to accept a product or service for operational use.

366

Table F-5 in Appendix F lists the inputs and outputs for the SI phase and associates the items with the SE element that produces them.

368

3.4.3.2 Solution Implementation Phase Inputs

369

The major inputs to the SI phase are:

370

371 • Work products from the outputs of the final IA stage have been completed to the version
372 level specified

373 • The final IPP has been completed

374 • The final IA decision (JRC 2b) has been made, authorizing the program to continue into
375 SI

376 Table 3.3-2 (column labeled JRC 3) lists the inputs, outputs and work products associated with
377 SI.

378 3.4.3.3 Solution Implementation Phase System Engineering Activities

379 Figure 3.2-1 lists the SE elements activities required to accomplish the SI objectives. While the
380 SE activities vary widely, depending on the program, the interactions of the SE processes
381 remain essentially the same as in the IA phase. Upfront, the activities involve finalizing and
382 baselining the system, its requirements, and the program to support its development and
383 operation. The SE effort then focuses on transforming the accepted concept into a product for
384 deployment. Thus, toward the beginning of the phase, the emphasis remains on the core SE
385 processes, which continue to refine the requirements and bring greater resolution to the design.
386 In the latter portion of this phase, the emphasis shifts to Verification activities (Section 4.12) to
387 verify that the system has been built and integrated according to the requirements. The final set
388 of SI activities consists of installing the product or initiating the service at each site and certifying
389 it for operational use, as appropriate, which typically includes implementation planning,
390 installation and checkout, integration and shakedown, dual operations, and removal and
391 disposal of obsolete equipment.

392 As in previous stages of SE efforts—in addition to the tasks identified below—it is
393 recommended that each SE element active during this phase surface concerns and issues that
394 present risk to the program.

395 Various reviews and audits are conducted throughout the SI phase to maintain proper oversight
396 of system development. Integrated Technical Planning (Section 4.2) discusses the following
397 reviews and audits, and they are defined in the glossary:

398 • System Requirements Review

399 • System Design Review

400 • Preliminary Design Review

401 • Critical Design Review

402 • Verification Readiness Review

403 • Functional Configuration Audit

404 • Physical Configuration Audit

405

406

3.4.3.4 Solution Implementation Phase Outputs

The primary output from the SI phase is as follows:

- The In-Service Decision has been made, authorizing the program to deploy and put the developed system into service

Table 3.3-2 (see JRC 3 column) lists the inputs, outputs, and work products associated with SI. As shown in Figure 3.4-4, final forms of the following documents are completed and/or updated by the end of this phase:

- Certification Package
- Interface Control Documents
- Test and Assessment Articles
- Configuration Description
- Functional and Physical Architecture
- Risk Summary and Mitigation Plans
- Requirements Verification Compliance Document

3.4.4 In-Service Management

In-Service Management involves two distinct sets of work activities. The first set monitors and assesses the real-world performance of the system against its requirements and expected benefits in the APB and takes action to optimize performance throughout its operational life. The second set of activities deals with operating and maintaining the system throughout its service life, as well as maintaining the physical and support infrastructure. The various SE elements are employed within both sets of these activities, and the elements appear in Figure 3.2-1. Regarding the latter set of activities, the results of SE efforts are used to support the decision-making process regarding when a new capability or improvement needs to be in place.

In addition to the timing decision, a decision is made regarding whether modifications or improvements are feasible within approved sustainment funding in the APB. If an engineering change to the system within the sustainment funding is unable to be supported, then the shortfall is addressed via the standard AMS lifecycle phases. Thus, the SE efforts for this route are as noted in "Mission Analysis Phase" (Paragraph 3.4.1), "Investment Analysis Phase" (Paragraph 3.4.2), and "Solution Implementation Phase" (Paragraph 3.4.3).

If the effort to modify and/or optimize system performance is within the scope of sustaining funds, then the various SE elements are employed much as in the SI phase but on a lesser scale. The specific SE process and associated level of effort depend on the scope of the upgrade. If a modification is made to sustain system operations beyond its planned service life, a new investment decision for a service life extension shall be requested. Again, the SE efforts during this phase are essentially the same as noted in Solution Implementation Phase regarding the pieces of the system that are being modified to extend the life of the system as a whole.

3.4.5 Disposal

SE efforts to support disposal of a system being replaced occur during the new system's SI phase. Lifecycle Engineering (Section 4.12) defines the process for planning and executing disposal activities. The Integrated Technical Planning process (Section 4.2) is used to develop a Disposal Plan under FAA Order 4800.2, Utilization and Disposal of Excess and Surplus Personal Property.

3.5 Reserved

3.6 Reserved

3.7 Guidance for Tailoring of System Engineering

This SEM defines the FAA SE elements along with the work products generated from these elements during each AMS phase. The 12 elements appear in Chapter 1 (Table 1.2-1). A 13th element is included to provide for process management and maintenance of the other 12 elements. These elements that have been defined are elements of better system engineering practices that have been designed to be tailored. Tailoring is deletion or reduction in depth of the application of any of these 12 elements. Tailoring is also the addition of unique or special focus elements or areas provided in organization policies and procedures or in an acquirer-supplier relationship.

3.7.1 Basic Principle of Tailoring of System Engineering

Whether large or small, hardware-intensive or software-intensive, people- or process-concentrated, many if not all of the SE elements apply. The magnitude and nature of the program determines which of the elements that apply and to what depth. Tailoring is determined by the appropriate system engineering management authority designated in the domain (or business unit)-level or IPT-level SEMP. The Chief System Engineer, Program Manager, or other dually authorized authority makes the tailoring decision and captures the rationale for eliminating or reducing the depth of each of the SE elements in the SEMP.

The intent here is not to overburden the lower-than-NAS-level organizations with mandated guidance, but to give them the prerogative to exercise judgment while maintaining awareness of the proven practices in the NAS-level SEM.

This principle does not mean that large, complex programs may be de-scoped, except under the ground rules listed in this section. The following paragraphs give examples of specific aspects of SE and how they are to be treated in a tailoring effort.

3.7.2 Tailoring of Acquisition Management System Process Phase Aspects of System Engineering

"AMS/System Engineering Work Products Inputs and Outputs" (Section 3.3) describes the AMS phases employed on all programs. It is recommended that these phases not be eliminated or combined on any program. However, they may be shorter in duration. Furthermore, it is recommended that the entrance and exit criteria for any phase not be ignored. In addition, it is recommended that the exit reviews associated with the phases not be eliminated. "Tailoring of Review Aspects of System Engineering" (Paragraph 3.7.5) discusses the reviews.

3.7.3 Tailoring of Planning Aspects of System Engineering

It is recommended that all plans pertinent to the program be written; however, some plans may be shortened to a single page or combined in a single document. When combined, the document that comprises the combining for the program contains the rationale and the justification for the combining. The most important plan is the IPP, a result of the SE element Integrated Technical Planning (Section 4.2). The IPP may be reduced to its essential elements, and individual entries may be as short as a single line. It is recommended that these aspects be retained:

- AMS Phases (Section 3.2)
- SE elements (Sections 4.2 through 4.14, as tailored)
- SE specialties to be employed on the program

3.7.4 Tailoring of System Engineering Element Aspects of System Engineering

It is recommended that individual programs tailor the application of processes, tools, and techniques according to program requirements, with implementation of these processes directed by the appropriate SE management authority.

It is recommended that program cost/benefit considerations be the basis for the allocation of appropriate resources, including manpower and schedule, to any process activity. As above, it is also recommended that the basis and rationale for tailoring SE elements be captured in the IPT level, business level or domain-level SEMP.

3.7.5 Tailoring of Review Aspects of System Engineering

Two rules prevail regarding this topic: (1) It is recommended that all major JRC reviews be performed at the end of each of the phases defined in the AMS, and (2) it is recommended that reviews not be combined; but, depending on the nature of the program/acquisition, the duration of time between the Initial IA and the Final IA could be abbreviated if all requirements are met. Additionally, a review may be shortened to an hour for a simple project. The moderator of the review confirms the basic purpose and ground rules of the review to ensure that they have not been compromised. Software reviews are only required if software is selected as a solution to the system requirements (discussed in "Tailoring of Software Aspects of System Engineering" (Paragraph 3.7.10)).

3.7.6 Tailoring of Functional Analysis Aspects of System Engineering

The Functional Analysis process (Section 4.4) is an example of a fundamental process, and it is recommended that its basic principles be maintained on programs of any size. On all programs, it is recommended that Functional Analysis be used to derive requirements in a structured and systematic method. The depth, scope, and tools used in developing the functional architecture may be tailored according to program complexity.

3.7.7 Tailoring of Requirements Management Aspects of System Engineering

The Requirements Management process (Section 4.3) is an example of a fundamental process, and it is recommended that its basic principles be maintained on programs of any size. On all programs, a Requirements Management tool is highly recommended, and the results are loaded into a master requirements database.

529 **3.7.8 Tailoring of Programmatic Risk Management Aspects of System Engineering**

530 It is recommended that the Risk Management process (Section 4.10) be performed on
531 programs of any size and throughout the lifecycle. The example forms provided in Risk
532 Management show that risk to the process is not paper-intensive. On the contrary, the Risk
533 Management process presented is extremely practical and adaptable to programs of any size.

534 **3.7.9 Tailoring of Verification Aspects of System Engineering**

535 The Verification process (Section 4.12) is one of the SE basic principles—it is recommended
536 that all requirements be verified. This is not to say that extensive testing is required, but simply
537 that it is recommended that steps be taken to ensure that the solution satisfies the
538 requirements. A simple analysis often provides that assurance. It is recommended that this
539 principle not be compromised on small programs. Failure to verify requirements may cause
540 small programs to turn unintentionally into large programs.

541 **3.7.10 Tailoring of Software Aspects of System Engineering**

542 Software is a solution to system (i.e., hardware and software) requirements. Hence, if software
543 is not selected as a solution, software reviews and other documentation are not required. If
544 software is required, standard software reviews and documentation are required. However, it is
545 not to be assumed that, if a program is designated as a software program, then the total system
546 aspects of SE might be ignored.

547 **3.7.11 Tailoring of Lifecycle Engineering Aspects of System Engineering (Reserved)**

548 **3.7.12 Tailoring of Synthesis Aspects of Systems Engineering**

549 It is recommended that the system engineering organization perform synthesis for the purpose
550 of defining design solutions and identifying subsystems to satisfy the requirements of the
551 verified functional architecture. Synthesis translates the functional architecture into a design
552 architecture that provides an arrangement of system elements, their decomposition, interfaces
553 (internal and external), and design constraints. The activities of synthesis involve selecting a
554 preferred solution or arrangement from a set of alternatives and understanding associated cost,
555 schedule, performance, and risk implications. Depending on the type of acquisition involved
556 (i.e., commercial-of-the-shelf items, nondevelopmental items, commercial hardware/developed
557 software, mix of solution processes, etc.), every aspect of synthesis need not be performed, or
558 the depth of every aspect that is performed need not be extensive.

559